REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
24/May/2001

2. REPORT TYPE
THESIS

3. DATES COVERED *(From - To)*

4. TITLE AND SUBTITLE
THE EFFICACY OF TRAINING DENTAL STUDENTS IN THE INDEX OF ORTHODONTIC TREATMENT NEED

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
LT COL BENTELE MARK J

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
OHIO STATE UNIVERSITY

8. PERFORMING ORGANIZATION REPORT NUMBER
CI01-76

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
THE DEPARTMENT OF THE AIR FORCE
AFIT/CIA, BLDG 125
2950 P STREET
WPAFB OH 45433

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Unlimited distribution
In Accordance With AFI 35-205/AFIT Sup 1

13. SUPPLEMENTARY NOTES

14. ABSTRACT

20010720 020

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE		45	19b. TELEPHONE NUMBER *(Include area code)*

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

DEPARTMENT OF THE AIR FORCE
48th TFW

25 March, 2001

MEMORANDUM FOR: Diana Jordan

FROM: Lt Col Mark J. Bentele

SUBJECT: Thesis reimbursement

1. Enclosed is an approved and signed copy of my thesis from The Ohio State University. I was AFIT/CIM sponsored for a masters degree program. A thesis was required for graduation from my program.

Mark J. Bentele, Lt Col, USAF, DC
4100 Kendale Road
Columbus, OH 43220

THE EFFICACY OF TRAINING DENTAL STUDENTS IN THE INDEX OF ORTHODONTIC TREATMENT NEED (IOTN)

A Thesis

Presented in Partial Fulfillment of the Requirements for

The Degree Master of Science in the

Graduate School of The Ohio State University

By

Mark Joseph Bentele, D.D.S.

*****

The Ohio State University

2000

Master's Examination Committee:

Katherine Dryland Vig, B.D.S., M.S., F.D.S., D. Orth., Advisor

Shiva Shanker, D.D.S., M.D.S., M.S.

F. Michael Beck, D.D.S., M.A.

Approved by:

Katherine Dryland Vig

Advisor
College of Dentistry

ABSTRACT

Orthodontic studies over several decades have found generally inconsistent agreement among dentists when evaluating orthodontic treatment need. There have also been recent reports that undergraduate dental education does not sufficiently prepare dentists to diagnose and make appropriate referrals of potential orthodontic patients. This highlights an opportunity to improve dental education in the area of orthodontic needs assessment. The Index of Orthodontic Treatment Need (IOTN) is an occlusal index that has been found to be both reliable and valid in studies both in Europe and in the United States. The IOTN's use as an educational tool has not been evaluated. The purpose of this study was to investigate the efficacy of IOTN as a tool to improve dental students' ability to assess orthodontic treatment need.

Fourth-year dental students were divided into three groups of twenty (control, sham-control, experimental). The subjects evaluated thirty orthodontic study models with a "gold standard" previously established by an expert panel of fifteen orthodontists for orthodontic treatment need. The control group evaluated the models on two separate occasions for orthodontic treatment need and the sham control group evaluated the models a second time after training in posterior-anterior cephalometrics. The

experimental group evaluated the models after IOTN instruction. Kappa, sensitivity and specificity were calculated for each subject.

For kappa, the ANCOVA result reveals a significant group effect ($p = 0.0001$), a significant gender effect ($p = 0.0289$), but no significant group by gender interaction ($p = 0.1762$). For sensitivity, there was no significant group effect ($p = 0.1007$), gender effect ($p = 0.6997$), or group by gender interaction ($p = 0.8644$). For specificity, there was a significant group effect ($p < 0.0001$), significant gender effect ($p = 0.0377$), but no significant group by gender interaction ($p = 0.4315$).

Teaching dental students the Index of Orthodontic Treatment Need significantly improved their agreement with an expert panel of orthodontists when determining orthodontic treatment need.

DEDICATION

This thesis is dedicated to my wife Donna and my sons Benjamin, Christof and Timothy.

Their love, devotion and sacrifices made this thesis possible and worthwhile.

ACKNOWLEDGMENTS

I would like to express my appreciation to Dr. Katherine Vig for her wise counsel during this project. I would also like to thank Dr. Shiva Shanker for his educational and administrative expertise. A special thanks to Dr. Michael Beck for leading me through the statistical jungle. Thank you to Dr. D.J. Burden for lending assistance in the design of the instructional materials. Thanks to my wife Donna for her proofreading help. I would also like to thank Levi Evalt for help organizing the subjects. Thanks also to the willing volunteers of the Ohio State University Dental College Class of 2000.

VITA

December 16, 1960......................	Born – Macon, Missouri
1979 – 1982..............................	University of Missouri, Columbia
1986..	D.D.S., University of Missouri-Kansas City School of Dentistry
1986 – 1987..............................	General Practice Residency, Ehrling Berquist Hospital, Offutt AFB, Nebraska
1986 – present..............................	United States Air Force Dental Corps
1997 – 2000..............................	Graduate Resident in Orthodontics, The Ohio State University, College of Dentistry

FIELDS OF STUDY

Major Field: Dentistry

Specialty: Orthodontics

TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

"…I am impressed with the belief that although diagnosis is the question of greatest importance, it is yet apparently the least intelligently studied and comprehended." Edward H. Angle, D.D.S., Classification of Malocclusion 1899[1]

Attempts to classify malocclusions, and by extension orthodontic treatment need, extend back to the dawn of the orthodontic specialty. Edward Angle's is the classic and most commonly utilized classification of malocclusion. However, Angle's classification is based primarily on antero-posterior molar relationship and has low validity in determining orthodontic treatment need[2].

Malocclusion is considered an expression of normal biological variation. Treatment need is often based as much on psychosocial concerns as on definitive pathology and associations between malocclusion and secondary oral disease are tenuous at best. Caries is better correlated with carbohydrate consumption than crowding and periodontal disease is more associated with socio-economic class than molar relation.[3,4] The criteria for determining orthodontic treatment need tend towards shades of gray rather than dichotomous choices and there is no infallible litmus test for proving that need. These factors make it particularly difficult for the general dentist to confidently ascertain orthodontic treatment need for their patients.

The increasing penetrance of managed care into dentistry and orthodontics in the United States brings to the forefront the same questions that have vexed care managers in Northern Europe. Given a limited amount of resources and increasing demand, how is orthodontic need fairly determined? The traditional pathway to orthodontic care passes through the general dentist's office. In a study by Shaw[5], 70 percent of orthodontic patients initially were prompted to seek orthodontic care by their general dentist. However, Richmond[6] found in some instances that the *intra-observer* agreement was equivalent to chance when dentists determine orthodontic treatment need.

Clearly, there appears to be a need for a triage device for objectively assessing orthodontic treatment need. An ideal index should be reliable, valid, convenient to use and acceptable to the orthodontic profession, referring dentists, consumers, and third party payers alike.[7] The Index of Orthodontic Treatment Need (IOTN) is designed to fulfill these objectives. IOTN ranks malocclusion in terms of the significance of various occlusal traits for the individual's dental health *and* the perceived aesthetic impairment.

The subjective criteria that dentists use to judge the need for orthodontic treatment have been reported in various studies to be unreliable with questionable scientific support. This suggests an opportunity to improve the pre-doctoral curriculum in the area of orthodontic needs assessment. An unexplored area of IOTN research is the utilization of this index as an educational tool in predoctoral dental education.

Literature Review

Limitations of subjective orthodontic assessment

Quantifying the degree of malocclusion and the need to treat are less definable than with oral disease. Both inter- and intra- examiner error have been found to be high when utilizing Angle's Classification.[2] Brash[8] reviewed the literature prior to the development of most currently used occlusal indices and found that the prevalence of normal occlusion ranged widely from 8.6 percent to 77.6 percent depending on the observer and method. Richmond's[6] 1994 investigation revealed that a panel of 74 dentists was divided as to what constituted a need for orthodontic treatment based on dental health grounds. However, Richmond did find a greater degree of agreement on the perception of unattractive versus attractive dentitions.

Subjective evaluation of treatment need by orthodontists has also been found to be unreliable and inaccurate. Ast[9] found that two orthodontists examining dental casts disagreed 30 percent of the time when using Angle's Classification. In a study of orthodontists by Keeling,[10] excellent subjective reliability existed only for evaluating the presence of posterior crossbite (kappa = 0.79). Surprisingly, the reliability of maxillary and mandibular anteroposterior positions, incisor display, interlabial gap, and maxillary crowding were poor (kappa < 0.40).

Comparisons of occlusal indices

Occlusal indices have not been used extensively in the US in comparison to Northern Europe. The impetus for the development and usage of occlusal indices has been based on National Health Service economics to prioritize treatment need when limited resources exist. The search for an ideal index is an ongoing struggle as evidenced

by the abundance of competing systems developed over the last 40 years. This has been an evolutionary process as some more recent indices adapted components of earlier instruments. In 1989, Turner[11] concluded from using the TPI, (1967, Grainger, Orthodontic Treatment Priority Index[12]), that it will be very difficult to produce an index that considers all aspects of malocclusion which can be used consistently by personnel untrained in orthodontics.

There have been numerous comparative studies of occlusal indices. The key areas of interest are validity, reliability and ease of use. A critical problem when evaluating the various occlusal indices is the establishment of a legitimate "gold standard" for comparison. There is no external criterion such as a biopsy that can confirm the conclusion of an occlusal index[13]. A commonly adopted method to establish a gold standard is to use a putative expert panel of orthodontists to determine orthodontic treatment need on a reference sample of patients or patient records.

Lindauer[14] compared the Salzmann Index, (1968, Salzmann, Handicapping malocclusion assessment, [HMAR][15]), with IOTN and concluded that different patients were likely to be approved for treatment depending on the index used. However, the Salzmann Index does not include an esthetic or psychosocial component. This was deemed important by the 1993 AAO Orthodontic Indices Conference[16].

The AAO Orthodontic Indices Conference concluded that:

a) The HLD, (1960, Draker, Handicapping Labio-Lingual Deviations [17]), while easy to use and reliable, lacked validity because of arbitrary weightings of factors.
b) The TPI was inappropriate for treatment need because it was not designed as an index.
c) The Salzmann Index was neither reliable nor valid.
d) Of the *new* indices, IOTN most merited further research into its reliability and validity.

Since IOTN has roots in Sweden with modifications in the U.K., it is important to consider it's cross-cultural adaptability. In the U.S., Younis[18] utilized Receiver Operating Characteristic curves to compare IOTN, HLD, HMAR and PAR, (1992, Richmond, Peer Assessment Rating[19]). They concluded that IOTN had the highest diagnostic accuracy with 98.6% under the curve with HLD at 96.1%, HMAR with 96.6% and PAR came in at 95.0%. Then So and Tang[20] tested IOTN against the OI (1966, Summers, Occlusal Index[21]), in Hong Kong. Although they felt neither was ideal, IOTN had the advantage of simplicity.

Beglin[22] in a comparative study concluded that DAI, HLD (Cal Mod) and IOTN were reliable and valid indices that aided in the assessment of orthodontic treatment need. He also found that these three indices exhibited high overall diagnostic performances that were in agreement with a panel of central Ohio orthodontists. This study utilized Receiver Operator Characteristic (ROC) curves to determine optimum cutoff points for each index. The cutoff points determined for IOTN were lower than previously recommended in Europe at 3 (vs 4) for the Dental Health Component and 5 (vs 8) for the Aesthetic Component. Beglin also found strong agreement between the subjective opinions of orthodontists in central Ohio and western Pennsylvania.

An index such as the DAI (1986, Cons and Jenny, Dental Aesthetic Index[23]) ranks patients on a scale from 13 to 80 to prioritize for care. This index has been considered to provide cross-cultural comparisons and has been widely adopted by health organizations worldwide. Due to the ongoing controversy regarding what exactly

determines orthodontic treatment need, an index such as IOTN that groups patients more broadly may provide the best balance between professional autonomy and administrative ranking.

IOTN development

While many earlier occlusal indices were developed for diagnostic classification or epidemiology, IOTN was designed to ascertain orthodontic treatment need. Brook and Shaw[24] developed IOTN after a review of the literature questioned conventional wisdom that a correlation existed between malocclusion and oro-facial health. It is comprised of two components:

i) The Dental Health Component (DHC) of IOTN is a distillation of the factors currently believed related to the deleterious health effects of malocclusion (Appendix A). It was modified from the index of treatment priority used by the Swedish National Board for Health and Welfare, (1974, Linder-Aronson, Swedish National Board for Health and Welfare Index[25]), and has five grades anchored by "no treatment need" to "great need". Five traits of dental occlusion are graded: missing teeth, amount of overjet, crossbites, displacement of contact points and overbite. The scores are not additive with the highest score for any individual trait as the basis for assigning a grade. This prevents someone with numerous minor defects from being prioritized over someone with a single severe trait such as cleft palate.

ii) The Aesthetic Component (AC) of IOTN consists of a 10-point scale, illustrated by a series of numbered photographs (Appendix A). These

were rated by lay individuals and a panel of orthodontists in a previous study for facial attractiveness, (SCAN Index, Standard Continuum of Aesthetic Need, Evans and Shaw, 1987)[26]. Patients are matched to the photos not on the particular malocclusion displayed but matched according to the severity of the aesthetic impairment.

Thirty years ago, Carlos[13] predicted that "Construction of an index of 'handicapping malocclusion' will not be possible until objective methods of measuring the effect of a malocclusion upon the individual in a psychologic and social (as well as physiologic) sense are developed." As a second-generation occlusal index, IOTN incorporates both a dental health component and an aesthetic component and thus provides a balanced approach to allocating need.

IOTN: Validity, Reliability and Utility

Brook and Shaw[24] developed IOTN and reported the initial reliability study in 1989. They reported a kappa agreement for the DHC that ranged from .731 to .797. This is in the "substantial" agreement range quoted for the kappa statistic. For the Aesthetic Component, the Pearson's correlation coefficient values ranged from .71 to .95 and this included the evaluations by the subjects themselves, a dental assistant and orthodontists. To give IOTN a range of flexibility, Brook and Shaw planned to establish treatment cut-off points to reflect the findings of subsequent validation studies.

IOTN has been shown to be reliable and valid. Shaw[27] found that a mixed panel of orthodontists and general dentists differed in the subjective evaluation of orthodontic treatment need in individual cases. However, there was a reasonably high correlation between the Dental Health Component of IOTN and the *collective* view of the panel and

the agreement with the Aesthetic Component was higher. Inter-examiner agreement was calculated using the kappa statistic and a high level of agreement was obtained for the Dental Health Component (kappa = .83) and substantial agreement for the Aesthetic Component (kappa = .72). In 1993, IOTN was modified in response to studies that showed varying degrees of validity and reliability. Grades for each component were grouped into: "no need", "borderline need" and "definite need".

The utility of an index refers to practical issues such as ease of use, acceptability to users and expedience. IOTN was investigated by Jones[28] who found that it was readily accepted by experienced dental epidemiological examiners and each examination averaged less than two minutes. Holmes[29] also explored the utility of IOTN. Among British orthodontists, 75% utilized at least the DHC component. "Quick", "simple" and "easy to use" were the most common descriptions the orthodontists used to describe IOTN.

Training

After an 8-hour calibration exercise, Jones[28] found that experienced dental epidemiologists had mean *weighted* kappas of .53 for the DHC and .51 for the AC. Jones also reported a Sensitivity of .72 and a Specificity of .90 after one calibration. Richmond[30] found that a group of dentists could be easily trained to record the Aesthetic and Dental Health Components of the Index of Orthodontic Treatment Need and the PAR index to a satisfactory level (weighted kappa > 0.75). This training course required three days. Lunn[31] took two days to train and calibrate experienced dental epidemiologists to an acceptable level (group means for AC = 0.56. and for DHC = 0.61). Two or three days of instruction would be a large proportion of dental students' lecture time devoted to

orthodontics. Calibrating dentists in the use of IOTN may be prohibitively time consuming when applying traditional instruction methods to a dental school setting.

Burden[32] conducted a field trial in Great Britain of an IOTN learning package for general dentists. Burden theorized that presenting the information in a self taught format would be more time efficient and acceptable to the general dentists than a typical two-day IOTN training session. In a randomized controlled trial, dentists were separated into an IOTN self trained group and into a group without exposure to IOTN training. Their orthodontic referral patterns were then evaluated. It was found that there was a significant improvement in the odds that a patient referred from the test group was in definite need of orthodontic treatment.

The quest for an infallible index may be elusive. However, IOTN strikes the best balance of; esthetics and health concerns, ease of use and precision, with tested reliability and validity. Also, IOTN is designed to be modifiable to reflect evolving research and changing societal standards. Shaw, Richmond and O'Brien[33], early proponents of IOTN, remarked that they had observed markedly different thresholds for orthodontic referral among dentists. They stated that the use of an index by general dentists as part of the routine evaluation of patients might go some way toward improving timely identification of potential orthodontic patients.

Recently an education outcomes assessment by Brightman[34] was initiated because Northern Ohio orthodontists were concerned about the number of referrals from general dentists. Concomitantly, fourth year dental students at the closest dental school (Case Western Reserve) expressed concern that they had no clinical experience in orthodontics and did not know how to apply didactic knowledge to clinical situations. Brightman

concluded that while didactic knowledge increased, orthodontic diagnostic skills did not substantially improve during undergraduate dental education. Consequently the ability to make appropriate referrals for treatment did not improve over the course of a dental education.

> (Students) '...had difficulty recognizing instances of spacing, crowding, overbite, overjet, and crossbite', and 'did not recognize unusual dental conditions such as congenitally absent, supernumerary, or impacted teeth.'

Though not all of the authors' concerns about diagnostic abilities would be satisfied with this index, IOTN specifically addresses the deficiencies noted above from this academic outcomes study.

CHAPTER 2

STATEMENT OF THE PROBLEM

The referral of patients for orthodontic care is an arbitrary process that is dependent as much on the observer as on the presenting malocclusion. Inconsistent or invalid standards for orthodontic referral result in some patients attending unnecessary orthodontic evaluations whilst other patients miss out on timely referrals for treatment. This highlights a deficiency in the diagnostic acumen of dental school graduates and in the dental school educational process.

The objective of this study was to explore the use of IOTN as an educational resource in a dental school setting. The specific aim was to demonstrate that IOTN training is an effective educational tool for improving the agreement of the orthodontic needs assessments of general dentists (students) more closely to that of orthodontists. An improvement in the agreement of orthodontic needs assessment between general dentists and orthodontists will enable the general dentist to function as a more effective evaluator of orthodontic treatment needs.

Hypothesis: Training dental students in IOTN will improve the agreement of their assessments of orthodontic treatment need when compared to an expert panel of orthodontists.

CHAPTER 3

MATERIALS AND METHODS

Subject selection

Fourth year dental students at The Ohio State University College of Dentistry volunteered to participate in this study. Participants were excluded if they had any experience with occlusal indices. Three stratified, random sample groups were produced with nearly equivalent mean grade point averages (GPA). Group 1 was the control; Group 2 was a sham control group to control for the "Hawthorne Effect"[35] and Group 3 was the experimental group. Each group initially contained 29 potential participants. Between 21 and 25 volunteers presented for the baseline assessment and attrition from T^1 to T^2 further reduced the number to the 20 per group predetermined by power analysis. There were no significant group differences for gender or GPA (Table 3.1).

Variable	*Control*	*Sham*	*Experimental*	*Statistic*	*df*	*P*
Gender	F=55% (11/20) M=45%(9/20)	F=30% (6/20) M=70%(14/20)	F=30% (6/20) M=70%(14/20)	X2=3.53	2	0.1716
GPA	3.11±0.46	3.12±0.48	3.03±0.41	F=0.69	2/57	0.5069

Table 3.1: Group gender and GPA comparisons (Mean±SD)

Orthodontic study models selection

Buchanan[36] established that IOTN might be applied to study models with substantial agreement to clinical IOTN evaluations. A set of orthodontic study models was previously duplicated from the archives of the University of Pittsburgh. This sample was used by: DeGuzman[37] for PAR validation, Younis[18] for validation of the IOTN, HMAR, HLD and PAR, and by Beglin[22] for validation of DAI, HLDCalMod and IOTN. In addition, Beglin established this set of casts as a viable gold standard by showing a high agreement between the opinions of orthodontists in western Pennsylvania and central Ohio (kappa = .83). In Beglin's study, orthodontic raters assigned a score to each of the casts on an adjectival scale where "1 equals none/minimal need" and "7 equals very great need". The raters then established an "Indicated Treatment Point" (ITP) at which orthodontic treatment was indicated. This cutoff point was calculated to be 3.53±.74. All casts below this point were in the 'no treatment' category and all models at or above were in the 'treatment' category.

An initial subsample of 11 casts with a full range of severity and IOTN conditions (missing teeth, overjet, crossbite, crowding, overbite) was selected for a pilot study. The pilot study findings were consistent with Popovich and Thompson's[38] work on the TPI. Predictably, there is less agreement among examiner's ratings when assessing low severity cases than when looking at more severe cases. Pilot study casts with severe malocclusions were likely to be correctly rated as requiring orthodontic treatment, whereas borderline cases were more difficult for the students to categorize. When the case obviously requires treatment there is less advantage to using an index for diagnosis.

Consequently, for the actual study, 30 models were selected that ranged from 2.00 to 5.13 on the 7-point scale. This yielded a more challenging test of their diagnostic abilities both baseline and after training.

Methods:

The selected 30 casts were arranged on a table in archival numbered order which had no relation to treatment need. The subjects were asked to determine orthodontic treatment need with the same instructions given to the orthodontic raters who established the gold standard. The word "referral" was added to reflect the non-specialist status of the subjects.

> "You are the consultant for a private corporation for which a fund has been established to provide orthodontic treatment for personnel. You are to evaluate these study casts and answer the following question: In your opinion, does this occlusion need referral for orthodontic treatment?"

All subjects produced baseline decisions at T^1 for orthodontic treatment referral: Yes or No. A binary decision (rather than, *No Need, Borderline Need* or *Definite Need*) was chosen to simplify testing for sensitivity and specificity.

Figure 3.1: Subject accomplishing baseline dental model assessment

The time from T^1 to T^2 was minimized to lessen the chance for other dental school training or communication between the groups to influence the results. The IOTN group was tested last to prevent knowledge of IOTN procedures from filtering out to the two control groups. The time from T^1 to T^2 for most subjects was 9 days but ranged up to 20 days.

At T^2, Group 1 (control) reevaluated the casts exactly as before. At T^2, Group 2 (sham) participated in an exercise on posterior-anterior cephalometrics. The subjects viewed a computer displayed PowerPoint© (Microsoft, Office 97) presentation and drew vertical and horizontal planes from Grummon's analysis[39] on provided tracings. They were informed that each group received different instruction and the research was searching for what type of instruction is useful for improving dental students' orthodontic diagnostic skills. They then reevaluated the casts exactly as before.

The experimental group viewed a PowerPoint© presentation similar to Burden's[33] handbook, "*A Guide to Assessing the Need for Orthodontic Treatment*". Instructional manuals identical to the presentation were also provided. This was viewed concurrently with a familiarization exercise for both the AC and the DHC. Two of the sets of models used in the presentation demonstrated several IOTN measurable traits and were duplicated so that each participant would have the opportunity to grade the same models. Once all participants verified accurate grading for each trait, the group moved on to the next IOTN trait. Emphasis was placed on the use of the acronym **MOCDO** (**M**issing, **O**verjet, **C**rossbite, **D**isplacement of contact points and **O**verbite) (Appendix A). After the presentation there was an opportunity to ask questions and clarify the instruction. To facilitate learning and accommodate schedule conflicts, subgroups of 3 to 7 were taught

over a 3-week period. One investigator provided all instruction. The instruction session was designed to fit within the time constraints of a standard lecture period and lasted from 30 to 45 minutes. At the conclusion of the instruction, the experimental group subjects were asked to regrade the models using IOTN. The subjects then made a referral/no referral decision based on their IOTN findings. Optimal cutoff points as established by Beglin were utilized (DHC = 3 and AC = 5).

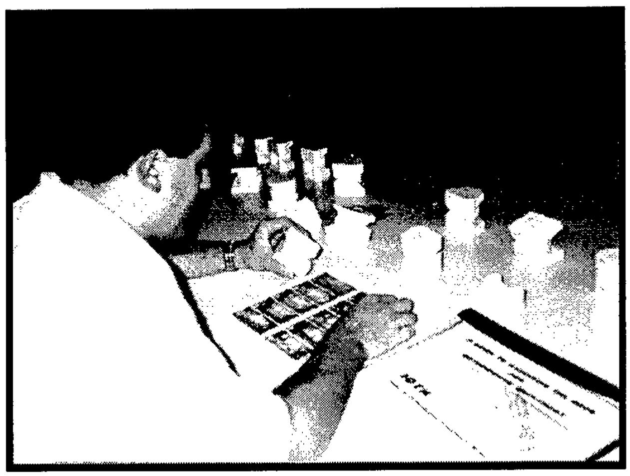

Figure 3.2: Subject utilizing IOTN to assess dental models

Materials: IOTN calibration models, IOTN training manuals and PowerPoint© presentation, Dental Health Component Rulers, Aesthetic Component Photographic Scale.

Independent variable: Instruction of dental students

Dependent variables: Final adjusted mean scores of: Kappa statistic, Sensitivity, Specificity

Data: Ratio

Statistical analysis methods:

Kappa (Cohen[40]) was used as a measure of inter-observer agreement on diagnostic tests. This experiment used a binary yes/no decision with no rank ordering so a simple kappa was utilized. Unlike percent agreement, kappa controls for agreement due to chance. Pearson's product-moment correlation coefficients measure only the associations between sets of ratings and do not take into account any systematic biases in ratings.[41]

Sensitivity ($^{\text{True +}}/_{\text{Total who truly have disease}}$): was used as a measure of the students' ability to identify those individuals requiring referral for orthodontic evaluation. The casts considered to truly have the "disease" were those at or above the average 3.53 ITP established by the expert panel of orthodontists. True positives are the number among this group correctly identified by the dental students.

Specificity ($^{\text{True -}}/_{\text{Total who truly don't have disease}}$) was used as measure of the students' ability to identify those individuals who did not require referral for orthodontic evaluation. The casts considered to not have the "disease" were those below the 3.53 cutoff. True negatives are the number among this group correctly identified by the dental students.

Final scores of the 3 dependent variables of kappa, sensitivity and specificity were analyzed for significant differences due to treatment effect (IOTN training) by using ANCOVA with the initial value as the covariate.

Bias/Confounding variables:

A volunteer sample of dental students may be biased toward a group that is more interested or knowledgeable in orthodontics than the average student. The "gold

standard" of local orthodontists may not reflect the opinions of North American orthodontists as a whole but it is the group to which these dental students will most likely refer to in the future. Subgroups for the experimental group at T^2 were smaller than the control and sham control subgroups. Utilizing a subsample of archival models of borderline treatment need is not a cross section of the local patient population.

Sample size and power analysis:

The pilot study determined variability among a group of 4th year dental students when making a referral decision. Six students assessed 11 casts that were evenly distributed among the 7 grades used in the orthodontists' assessment. For kappa, the mean was 0.711 with a SD of 0.182. For an α level of 0.05 and a power of 80%, a sample size of 20 was adequate to detect a change in kappa of 0.12.

CHAPTER 4

RESULTS

For kappa, the ANCOVA revealed significant group effect ($F = 10.8$, $df = 2/53$, $p = 0.0001$) a significant gender effect ($F = 5.04$, $df = 1/53$, $p = 0.0289$) but no significant group by gender interaction ($F = 1.79$, $df = 2/53$, $p = 0.1762$).

For sensitivity, there was no significant group effect ($F = 2.40$, $df = 2/53$, $p = 0.1007$), gender effect ($F = 0.15$, $df = 1/53$, $p = 0.6997$) or group by gender interaction ($F = 0.15$, $df = 2/53$, $p = 0.8644$).

For specificity, there was a significant group effect ($F = 13.3$, $df = 2/51$, $p < 0.0001$), significant gender effect ($F = 4.55$, $df = 1/51$, $p = 0.0377$) but no significant group by gender interaction, ($F = 0.85$, $df = 2/51$, $p = 0.4315$).

	Control	*Sham*	*Experimental*	*Main Effect for Gender*
Female	0.452±0.046 (N = 11)	0.298±0.063 (N = 6)	0.559±0.062 (N = 6)	0.436±0.033 (N = 23) **a**
Male	0.439±0.051 (N = 9)	0.465±0.041 (N = 14)	0.686±0.041 (N = 14)	0.530±0.026 (N = 37) **b**
Main Effect for Group	0.445±0.034 (N = 20) **A**	0.381±0.038 (N = 20) **A**	0.623±0.038 (N = 20) **B**	

Table 4.1: Kappa Results (Adjusted Final Scores)
Means with dissimilar letters differ significantly ($p<0.05$)

	Control	*Sham*	*Experimental*	*Main Effect for Gender*
Female	85.1±3.6 (N = 11)	82.8±5.1 (N = 6)	93.7±5.1 (N = 6)	87.2±2.6 (N = 23) **a**
Male	85.2±4.0 (N = 9)	82.8±3.3 (N = 14)	89.7±3.3 (N = 14)	85.9±2.0 (N = 37) **a**
Main Effect for Group	85.1±2.7 (N = 20) **A**	82.8±3.0 (N = 20) **A**	91.7±3.0 (N = 20) **A**	

Table 4.2: Sensitivity Results (Adjusted Final Scores)
No significant differences

	Control	*Sham*	*Experimental*	*Main Effect for Gender*
Female	59.6±4.2 (N = 11)	48.1±5.9 (N = 6)	61.0±5.81 (N = 6)	56.2±3.1 (N = 23) **a**
Male	61.3±4.82 (N = 9)	61.6±4.95 (N = 14)	72.9±4.09 (N = 14)	65.3±2.7 (N = 37) **b**
Main Effect for Group	60.4±3.2 (N = 20) **AB**	54.8±3.6 (N = 20) **A**	67.0±3.4 (N = 20) **B**	

Table 4.3: Specificity Results (Adjusted final scores)
Means with dissimilar letters differ significantly ($p<0.05$)

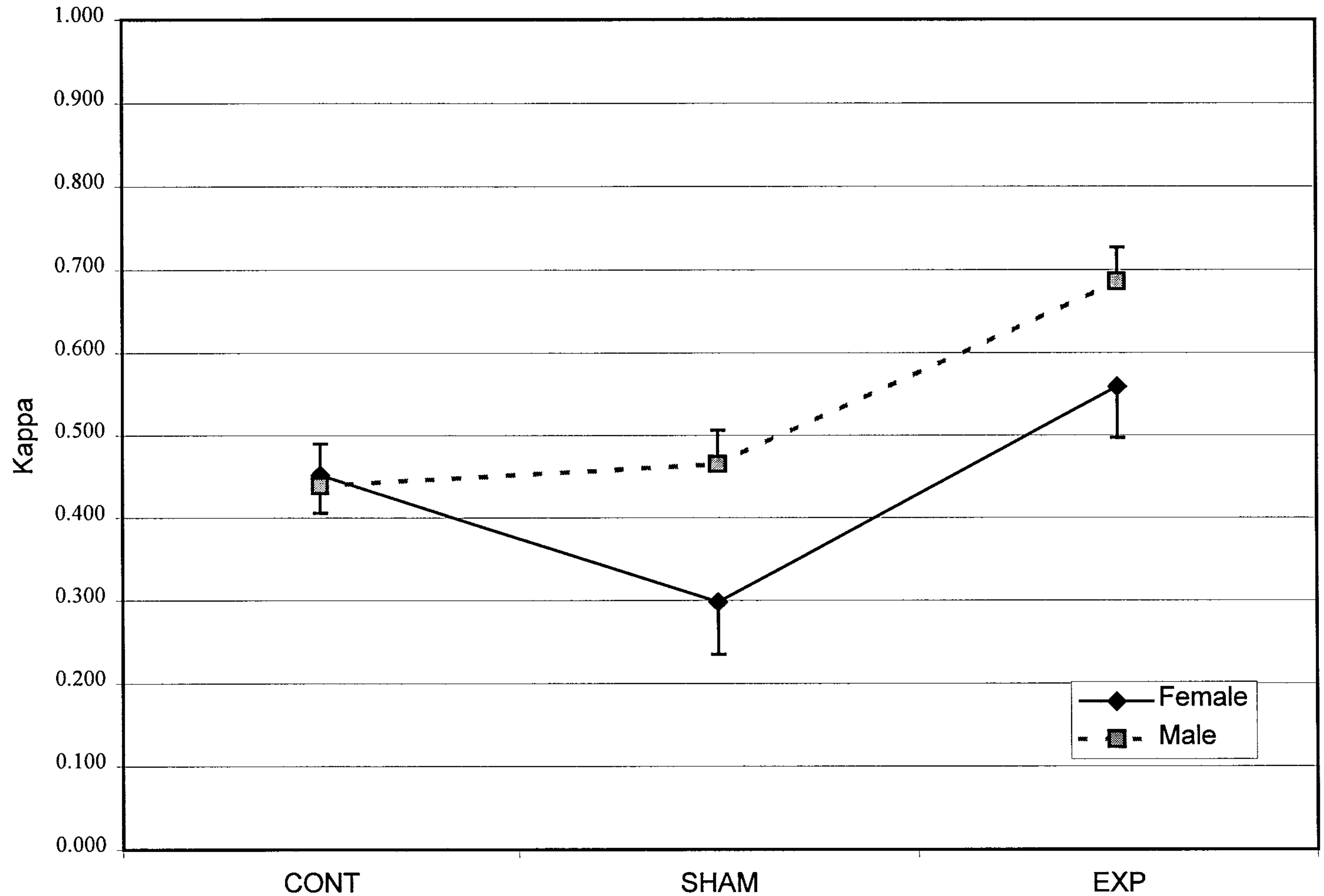

Figure 4.1: Adjusted Kappa Values (±SE)

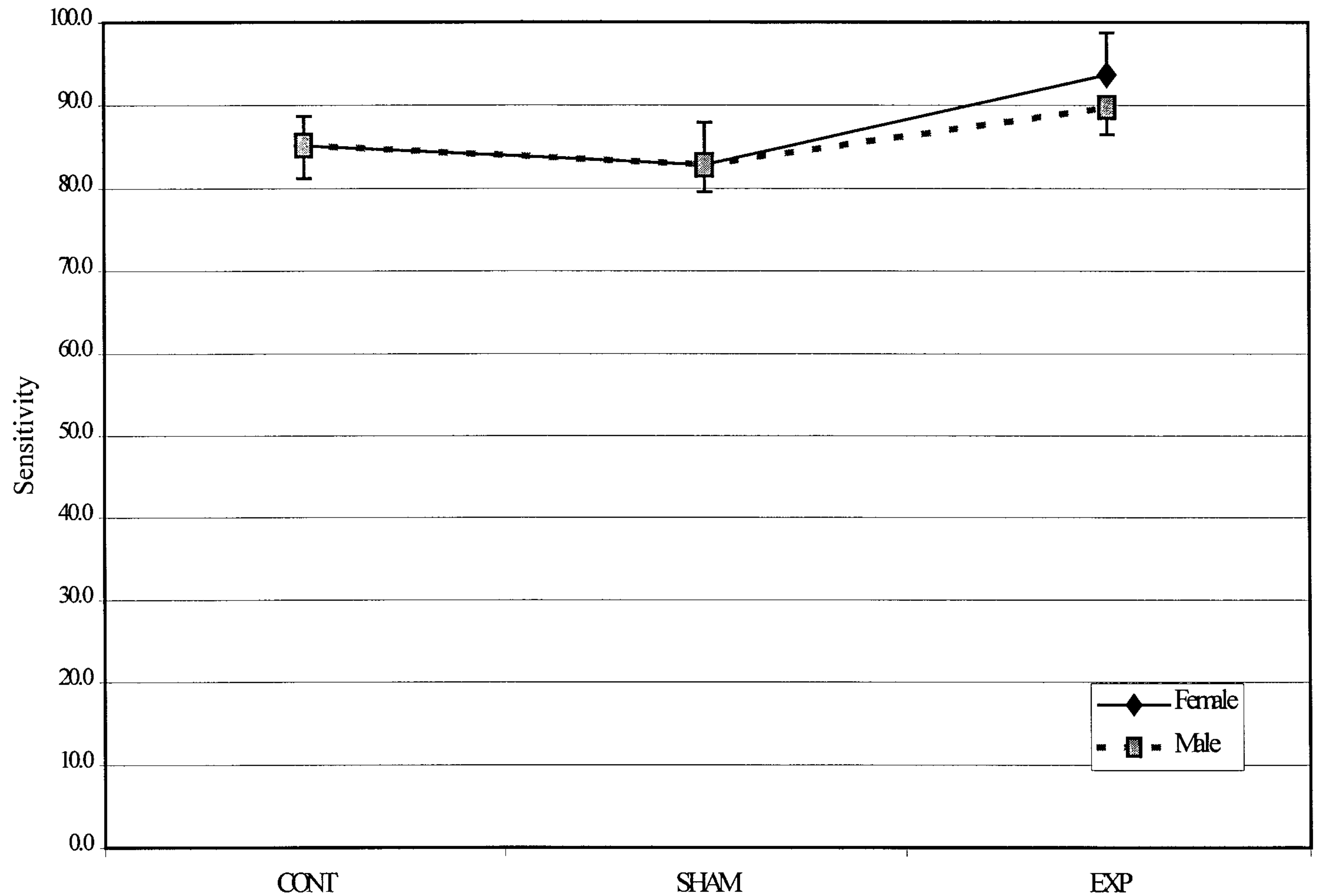

Figure 4.2: Adjusted Sensitivity Values (±SE)

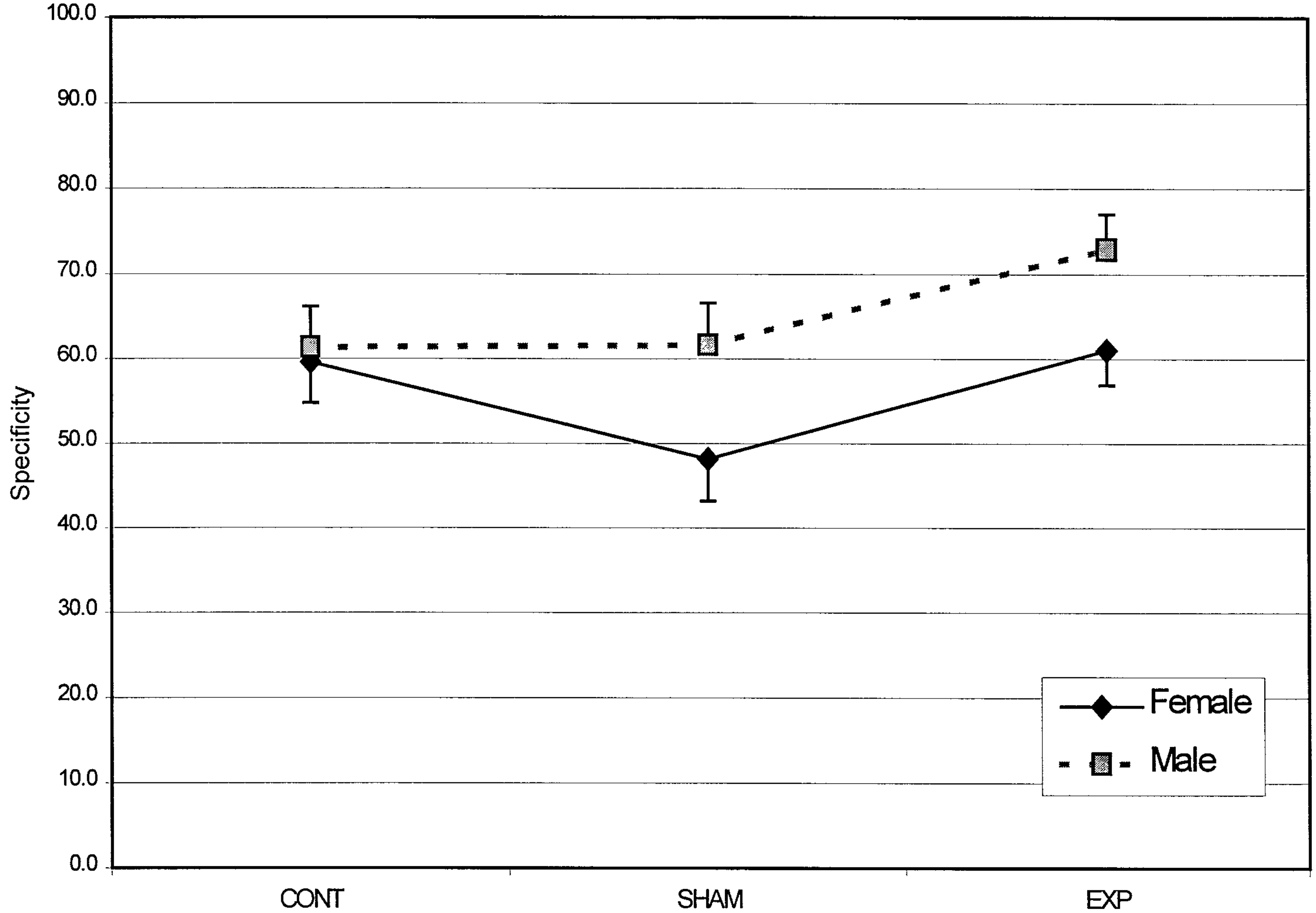

Figure 4.3: Adjusted Specificity Values (±SE)

CHAPTER 5

DISCUSSION

This study showed that the Index of Orthodontic Treatment Need is an effective educational resource to improve the agreement of fourth-year dental students' orthodontic evaluations to the evaluations of an expert panel of orthodontists.

At T^1 Kappa scores for the three groups ranged from fair to moderate strength of agreement. This finding conforms to previously cited literature[2,6,8-10] on the generally inconsistent subjective agreement amongst dentists when evaluating orthodontic treatment need. At T^2 the experimental group's final adjusted mean showed *Substantial* agreement whereas the control groups displayed only *Fair* to *Moderate* agreement.

Kappa Statistic	Strength of Agreement
< 0.0	Poor
0.00-0.20	Slight
0.21-0.40	Fair
0.41-0.60	Moderate
0.61-0.80	Substantial
0.81-1.00	Almost perfect

Table 5.1: Evaluation of the Kappa Statistic (Landis & Koch, 1977)[42]

Variable	*Control*	*Sham*	*Experimental*	*F*	*df*	*P*
Kappa	0.400±0.170	0.501±0.163	0.380±0.174	2.79	2/57	0.0698
Sensitivity	82.7±12.6	81.9±15.2	81.9±19.7	0.02	2/57	0.9822
Specificity	56.3±18.5	67.5±16.2	55.0±18.6	2.99	2/57	0.0583

Table 5.2: Initial Group Means for Dependent Variables (T^1) (± SD)

The dental students' baseline mean sensitivity indicated an adequate subjective ability to detect the patients requiring treatment. However, the lower specificity mean values indicate the high sensitivity was partially attained with a high false positive rate. If in doubt, the students assigned the patient to the referral category reducing the number correctly identified in the nonreferral category.

IOTN training had no significant effect on sensitivity. Since sensitivity started relatively high there was little room for a positive effect. It is reassuring to note that at baseline the dental students were able to correctly identify the majority of patients that would benefit from orthodontic treatment.

Mean adjusted specificity values in the experimental group were significantly higher than the sham control group but not significantly higher than the control group. This may be partially attributable to a positive treatment effect on the males in the experimental group and partially to a decline in performance of the females in the sham control group.

This investigation also detected a performance difference due to gender. Group composition did not differ significantly due to gender (Table 3.1) and analysis of GPA distribution by gender showed no significant difference ($F = 0.690$, $df = 2/57$, $p = 0.5065$). Males produced significantly better final adjusted mean kappa and specificity values compared to the females. It is not known if the differences are attributable to systematic biases in the research design, learning differences or if there are innate gender differences when assessing orthodontic treatment need.

A literature search for gender differences in dental education yielded no matches. General educational and child development literature is replete with reports on gender

differences in learning. Severiens and Ten Dam[43]utilized meta-analysis to review gender differences in learning styles. Out of 16 learning styles categorized, 12 displayed gender differences. Males consistently show a predilection for abstract styles of learning whereas females are more adept at concrete methods. The genders also differ on the underlying motivation for learning. Males tend to be more extrinsically motivated for what the learning will offer them. Females are more likely to be intrinsically motivated in learning for learning's sake.

Of particular interest to dental education, Linn and Petersen[44] performed a meta-analysis on gender differences for tasks involving spatial ability. Their analysis of the literature revealed that large gender differences exist on measures of mental rotation and that smaller but significant gender differences are found on measures of spatial perception. For tasks involving mental rotation the primary gender difference seems to be speed of rotation. Kail[45] found a bimodal distribution of females for tasks involving mental rotation. Some females performed as well as the males but there was a separate group of females that performed slower than all of the males. Linn and Petersen concurred that females differ from males mainly on speed of mental rotation but found the genders did not differ on accuracy. However, this may hinder performance on tests that require a large number of tasks in a short period of time because the female strategy is a more cautious approach with more double checking. Although this IOTN investigation was not specifically on mental rotation, a similar cautious strategy when confronted with 6 spatial tasks for each of the 30 dental casts may have been counterproductive.

Another possible explanation for the performance differences related to gender is the composition of the expert panel. The gold standard used for this investigation is based on the opinions of a panel of 15 male orthodontists. Rather than spatial or learning differences females may weigh aspects of malocclusion differently than males.

It is not possible to say what aspect of gender differences contributed to the results in this investigation. It is known that males and females utilize different strategies for learning and spatial perception. This is a topic for future dental education research and subsequent investigations into malocclusion assessment should consider controlling for gender.

Current research[3,4] finds few proven links between ideal occlusion and oral-facial health which may leave the general dentist in a quandary on whom to refer. An index provides some measure of objectivity so that the referring dentist may confidently counsel dental patients on the relative need for orthodontic treatment as a part of risk/benefit/cost analysis. IOTN provides a springboard for communication so that a patient may be informed of their specific orthodontic needs thus fostering realistic treatment objectives and expectations.

The educational community is increasingly adopting quality improvement methods from the business world. Establishing baseline performance levels and monitoring outcomes of improvement initiatives are cornerstones of the quality improvement movement. Although limited in scope to one school, dental students' baseline orthodontic diagnostic performance may be inferred from Brightman's[34] work. The dental school experience may adequately prepare a student to take the National

Board but may do little to improve a student's clinical orthodontic diagnostic expertise. This study validated a potential method to improve orthodontic educational outcomes.

The orthodontic profession in the U.S. has been hesitant to embrace the usage of occlusal indices because of a fear of bureaucratic imposition on professional autonomy. A key point of this study is that IOTN training improved the agreement of prospective general dentists not with a bureaucratic standard but with their local orthodontists. The IOTN may now be viewed as not only a valid, reliable occlusal index but also as an efficacious resource for dental education.

CHAPTER 6

CONCLUSIONS

1. Teaching dental students IOTN significantly improved their agreement with an orthodontic gold standard as measured by kappa.
2. Teaching dental students IOTN did not significantly improve their identification of patients who did not require treatment as measured by specificity.
3. Teaching dental students IOTN did not significantly improve their identification of patients who did require treatment as measured by sensitivity

APPENDIX A

PROTOCOLS FOR IOTN

Introduction

Aesthetic Component

Dental Health Component

IOTN Protocol

Introduction

Traditional orthodontic thinking has emphasized that the major benefits of orthodontic treatment are (i) the improvement of physical function, (ii) the prevention of tissue destruction and (iii) the correction of aesthetic impairment (British Dental Association, 1954, Standing Dental Advisory Committee, 1973). However, contemporary orthodontic opinion doubts the importance of orthodontic care in the prevention of caries, periodontal disease and TMJ disorders. For example, it has not been shown that individuals with ideal occlusions have significantly less caries, less periodontal disease and function better than individuals with malocclusion. Nevertheless, social science research indicates that unacceptable dental appearance, including visible dental characteristics that deviate greatly from the norm may stigmatize, impede career advancement and peer group acceptance, encourage negative stereotyping and have a negative effect on self concept (Cons, Jenny and Kohout, 1986). Indeed, patients seek orthodontic treatment more often for aesthetic rather than functional considerations on the basis that failure to meet social norms for dental aesthetics may have undesirable psychological effects. As a result any meaningful index of treatment need must include a component designed to measure aesthetics and by implication the likely level of psychological disadvantage.

INDEX OF ORTHODONTIC TREATMENT NEED

The Index of Orthodontic Treatment Need (IOTN) attempts to rank malocclusion in terms of the significance of various occlusal traits for an individual's dental health and perceived aesthetic impairment. It intends to identify those individuals who would most likely benefit from orthodontic treatment. The index incorporates an Aesthetic and Dental Health Component (Brook and Shaw, 1989)

AESTHETIC COMPONENT (AC)

The Aesthetic Component consists of a scale of ten colour photographs showing different levels of dental attractiveness (Evans and Shaw, 1987). The dental attractiveness of prospective patients can be rated with reference to this scale. Grade 1 represents the most and grade 10 the least attractive arrangements of teeth. The score reflects the aesthetic impairment. Monochrome photographs are used for dental cast assessment (Figure 1). These have an advantage in that raters are not influenced by oral hygiene, gingival conditions or poor colour matches in restorations affecting anterior teeth (Woolass and Shaw, 1987).

THE AESTHETIC COMPONENT OF IOTN FOR DENTAL CAST USE

Grades 1,2,3, and 4 – No/slight need for treatment
Grades 5,6, and 7 – Moderate/borderline need for treatment
Grades 8,9, and 10 – Need for orthodontic treatment

"Here is a set of photographs showing a range of dental attractiveness. Number 1 is the most attractive and 10 the least attractive arrangements. Where would you put your teeth on this scale?"

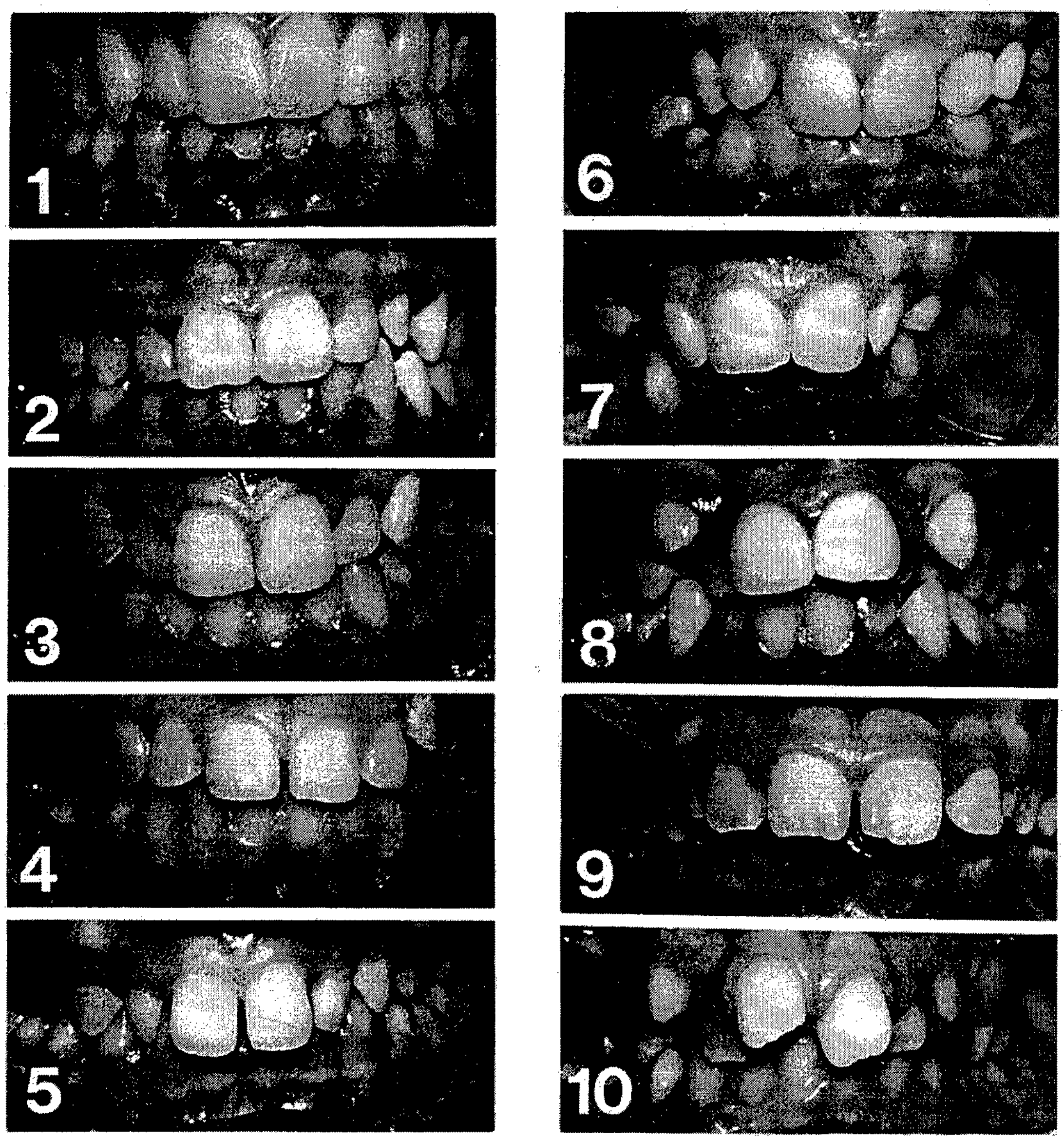

Figure A.1: The Aesthetic Component of IOTN for Dental Cast Use

Dental Health Component (DHC)

The DHC facilitates a synthesis of the current evidence for the deleterious effects of malocclusion (Brook, 1987). It is loosely based on the Index of the Swedish Medical Health Board (Linder Aronson, 1974). The Swedish Index was intended to be a basic guide, and its practical implementation called for a 'good sense of judgement'. The DHC was developed to reduce this subjectivity in measurement, with well defined cut off points. The DHC records the various occlusal traits of a malocclusion that would increase the morbidity of the dentition and surrounding structures. There are five grades, Grade 1 – 'No need for treatment' to Grade5 – 'Very great need'. Cleft Palate, severe overjets greater than 9mm would fall into grade 5. Displacements between contact points less than 1mm would fall into grade 1. Importantly, only the worst occlusal feature is recorded. The components that make up the five grades are shown in Table 1.

HIERARCHIAL SCALE

To help identify the worst occlusal feature a hierarchical scale of occlusal anomalies has been developed.

This hierarchical scale has two purposes:

a) to provide a guide which enables the examiner to survey the dentition in a systematic manner, and thus ensures all relevant occlusal anomalies are identified.

b) when two or more occlusal anomalies are found to achieve the same Dental Health Component grade the hierarchical scale is employed to determine which occlusal anomaly should be recorded. In this situation the occlusal anomaly higher up the order is recorded.

The hierarchical scale is as follows:

1. **M**issing teeth (including congenital absence, ectopic and impacted teeth).
2. **O**verjets (including reverse overjets).
3. **C**rossbites.
4. **D**isplacements of contact points.
5. **O**verbites (including open bites).

The acronym "**MOCDO**" can be constructed from the first letter of each category. This may be used to remember the hierarchical scale.

GRADE 5 (Need treatment)	
5.i	Impeded eruption of teeth (except for third molars) due to crowding displacement, the presence of supernumerary teeth, retained deciduous teeth and any pathological cause.
5.h	Extensive hypodontia with restorative implications (more than 1 tooth missing in any quadrant) requiring pre-restorative orthodontics.
5.a	Increased overjet greater than 9mm.
5.m	Reverse overjet greater than 3.5mm with reported masticatory and speech difficulties.
5.p	Defects of cleft lip and palate and other craniofacial anomalies.
5.s	Submerged deciduous teeth.

GRADE 4 (Need treatment)	
4.h	Less extensive hypodontia requiring prerestorative orthodontics or orthodontic space closure to obviate the need for a prosthesis.
4.a	Increased overjet greater than 6mm but less than or equal to 9mm.
4.b	Reverse overjet greater than 3.5mm with no masticatory or speech difficulties.
4.c	Anterior or posterior crossbites with greater than 2mm discrepancy between retruded contact position and intercuspal position.
4.1	Posterior lingual crossbite with no functional occlusal contact in one or both buccal segments.
4.d	Severe contact point displacements greater than 4mm.
4.e	Extreme lateral or anterior open bites greater than 4mm.
4.f	Increased and complete overbite with gingival or palatal trauma.
4.t	Partially erupted teeth, tipped and impacted against adjacent teeth.
4.x	Presence of supernumerary teeth.

GRADE 3 (Borderline need)	
3.a	Increased overjet greater than 3.5mm but less than or equal to 6mm with incompetent lips
3.b	Reverse overjet greater than 1mm but less than or equal to 3.5mm.
3.c	Anterior or posterior crossbites with greater than 1mm but less than or equal to 2mm discrepancy between retruded contact position and intercuspal position.
3.d	Contact point displacements greater than 2mm but less than or equal to 4mm.
3.e	Lateral or anterior open bite greater than 2mm but less than or equal to 4mm.
3.f	Deep overbite complete on gingival or palatal tissues but no trauma.

GRADE 2 (Little)	
2.a	Increased overjet greater than 3.5mm but less than or equal to 6mm with competent lips.
2.b	Reverse overjet greater than 0mm but less than or equal to 1mm.
2.c	Anterior or posterior crossbite with less than or equal to 1mm discrepancy between retruded contact position and intercuspal position.
2.d	Contact point displacements greater than 1mm but less than or equal to 2mm.
2.e	Anterior or posterior openbite greater 1mm but less than or equal to 2mm.
2.f	Increased overbite greater than or equal 35mm without gingival contact.
2.g	Pre-normal or post-normal occlusions with no other anomalies (included up to half a unit discrepancy).

GRADE 1 (None)	
1.	Extremely minor malocclusions including contact point displacements less than 1mm.

Table A.1: The Dental Health Component of the Index of Orthodontic Treatment Need

The Dental Health Component Ruler

A ruler has been designed containing all the information necessary to record the DHC (albeit in brief form). The ruler (Figure 2) has been developed for the clinical setting in which information is collected regarding competence of the lips, displacement on closure and masticatory speech problems. Only the worst occlusal feature is recorded. When recording overjet, the ruler is held parallel to the occlusal plane and radial to the line of the arch. The most prominent aspect of the upper incisors is recorded.

There are two ways of recording the DHC. The first is to record the grade only; in the second, the initiating feature would be recorded, for example, an overjet greater than 9mm would be 5.a (the grade being 5 and the overjet signified by the letter). The second method provides more information regarding the prevalence of the specific occlusal traits.

DENTAL CASTS PROTOCOL (For Use In The Absence Of Clinical Information)

The Dental Health Component is usually recorded at the chairside by direct examination of the subject but can also be recorded from dental casts. When using dental casts alone it is unlikely that clinical information will be readily available to the examiner. For this reason a protocol has been developed which should be employed when using dental casts. The protocol always assumes the worst scenario.

1. Overjets 3.5mm- 6mm on dental casts.
   Assume the lips are incompetent and award the grade 3a.

2. Crossbites on dental casts.
   Assume a discrepancy between retruded contact position and intercuspal position of greater than 2mm is present and award grade 4c.

3. Reverse overjets on dental casts.
   Assume that masticatory or speech problems are present.

THE DENTAL HEALTH COMPONENT RULER

This section provides a brief Description of occlusal anomalies. The majority are qualitative measurements.

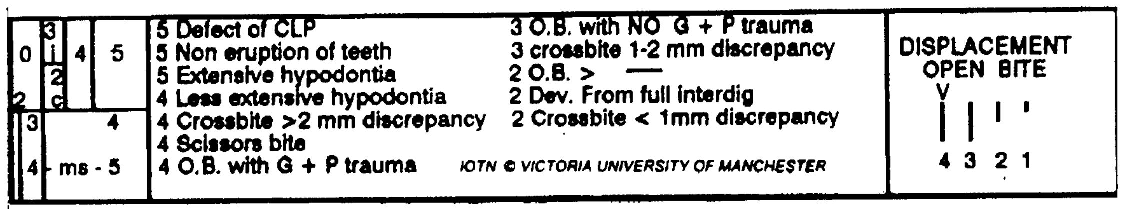

Figure A.2: The Dental Health Component Ruler

OVERJET
This section is split into two, the upper half records positive overjet, the lower half reverse overjet.

ABBREVIATIONS
i - incompetent lips
c - competent lips
O.B. - Overbite
G+P - Gingival and palatal trauma
Dev - Deviation
Interdig - Interdigitation

CONTACT POINT DISPLACEMENT AND OPENBITE
This section consists of four lines. Each line is assigned a grade. The greater the contact point displacement or open bite the greater the grade.

Conventions for the Index of Orthodontic Treatment Need (IOTN)

From experience in using and teaching the DHC we and other users found that there were many instances where the criteria were open to interpretation. As a result, a series of conventions were drafted to reduce this subjectivity.

BUCCAL OCCLUSION

In a good buccal segment the canines, premolars and molars interdigitate fully regardless of whether a full Class II and III relationship is present. However, if any of these teeth deviate from full interdigitation the DHC grade will be 2.g.

CROSSBITE

A tooth is in crossbite when:-
Anterior – 1 to 3 incisors are in lingual occlusion
Posterior – cusp to cusp or in full crossbite.

CROWDING

If the space between two teeth next to an unerupted tooth is less than or equal to 4mm, then this tooth is regarded as impacted, therefore the DHC grade will be 5.i.

Upper		
canine	8mm	
1^{st} premolar	7mm	TOTAL = 22mm (Impaction <=18mm)
2^{nd} premolar	7mm	
Lower		
canine	7mm	
1^{st} premolar	7mm	TOTAL = 21mm (Impaction <=17mm)
2^{nd} premolar	7mm	

CONTACT POINT DISPLACEMENT

The contact point displacement is measured between anatomical contact points when the teeth deviate from the line of the arch. Displacements between deciduous teeth and between deciduous teeth and permanent teeth are not recorded.

IMPEDED ERUPTION

If a tooth is unerupted due to the contact or close approximation of adjacent teeth, then the Dental Health Component grade would be 5.i (impaction)

If a tooth has erupted but there is insufficient space in the arch, the displacement score is recorded in terms of contact point displacement. If a tooth has not full erupted to the occlusal plane but has tipped against its adjacent tooth, this would score 4.t.

OVERJET

The overjet is measured using the ruler held parallel to the occlusal plane and radial to the line of the arch. The overjet is recorded to the labial aspect of the incisal edge of the most prominent incisor. A reverse overjet is recorded when all four incisors are in lingual occlusion.

ROTATION OF TEETH

Displacements between contact points of rotated teeth are not recorded. If the rotations cause a discrepancy between retruded contact position (RCP) and intercuspal position (IP), due to cuspal interference, this would then follow similar gradings to crossbite.

SPACING

Spacing is not generally recorded in the Dental Health Component. If spacing is associated with teeth deviating from the line of the arch, the contact point displacement score is recorded. If teeth have been extracted the residual spacing is not recorded.

SUBMERGING DECIDUOUS TEETH

Submerging teeth are not recorded unless only two cusps of the tooth remains visible and/or the adjacent teeth are severely tipped towards each other and closely approximated. In this case, the DHC grade would be 5.s.

PATH OF CLOSURE

Discrepancies between intercuspal and retruded contact positions are rated and are recorded in a similar manner to crossbites.

Guidelines

SYSTEMISATION

Use the "MOCDO" acronym

BORDERLINE CASES

If an occlusal trait is borderline, the lower DHC grade should be recorded.

AESTHETIC COMPONENT

The anterior teeth should be graded in their dental attractiveness as seen, no attempt should be made to predict the future appearance of the dentition. Stained restorations, chipped teeth, poor gingival conditions etc. should be ignored in this assessment.

PATIENTS' ASSESSMENT

The patient should be asked: "Here is a series of 10 photographs showing a range of dental attractiveness. Number 1 is the most, and 10 the least attractive arrangement of teeth. Where would you put your teeth on this scale?"

APPENDIX B

SUBJECT DEPENDENT VARIABLE SCORES

SUBJECT	GROUP 1=Control 2=Sham 3=Exp	KAPPA1	SEN1	SPE1	KAPPA2	SEN2	SPE2
1	1	0.6479	88.9	75	0.7222	88.9	83.3
2	1	0.1176	77.8	33.3	0.5588	94.4	58.3
3	1	0.1935	100	16.7	0.1935	100	16.7
4	1	0.2466	66.7	58.3	0.0278	61.1	41.7
5	1	0.4928	88.9	58.3	0.3056	72.2	58.3
6	1	0.2857	100	25	0.1791	83.3	33.3
7	1	0.2466	66.7	58.3	0.3284	88.9	41.7
8	1	0.2667	61.1	66.7	0.4	66.7	75
9	1	0.4	66.7	75	0.7297	83.3	91.7
10	1	0.3478	83.3	50	0.2647	83.3	41.7
11	1	0.6377	94.4	66.7	0.6377	94.4	66.7
12	1	0.507	83.3	66.7	0.557	61.1	100
13	1	0.507	83.3	66.7	0.4776	94.4	50
14	1	0.5833	83.3	75	0.5833	83.3	75
15	1	0.5833	83.3	75	0.5714	88.9	66.7
16	1	0.5588	94.4	58.3	0.3939	94.4	41.7
17	1	0.4	66.7	75	0.7143	94.4	75
18	1	0.1429	72.2	41.7	0.3478	83.3	50
19	1	0.5588	94.4	58.3	0.4928	88.9	58.3
20	1	0.2857	100	25	0.1935	100	16.7
21	2	0.3478	83.3	50	0.1176	77.8	33.3
22	2	0.2308	50	75	0.2667	61.1	66.7
23	2	0.4	66.7	75	0.5714	88.9	66.7
24	2	0.6753	72.2	100	0.7222	88.9	83.3
25	2	0.3421	61.1	75	0.5588	94.4	58.3
26	2	0.5455	100	50	0.375	100	33.3
27	2	0.4286	83.3	58.3	0.4928	88.9	58.3
28	2	0.7059	100	66.7	0.4615	100	41.7
29	2	0.375	100	33.3	0.4776	94.4	50
30	2	0.5946	77.8	83.3	0.4444	77.8	66.7
31	2	0.5455	100	50	0.1892	61.1	58.3
32	2	0.7222	88.9	83.3	0.3243	66.7	66.7
33	2	0.4595	72.2	75	0.5588	94.4	58.3
34	2	0.2667	61.1	66.7	0.1791	83.3	33.3
35	2	0.6479	88.9	75	0.6667	77.8	91.7
36	2	0.7143	94.4	75	0.6269	100	58.3
37	2	0.3836	72.2	66.7	0.375	50	91.7
38	2	0.7059	100	66.7	0.4118	88.9	50
39	2	0.5946	77.8	83.3	0.6053	72.2	91.7
40	2	0.3284	88.9	41.7	0.4928	88.9	58.3

Table B.1: Subject Dependent Variable Scores

Continued

Table B.1 Continued

SUBJECT	GROUP	KAPPA1	SEN1	SPE1	KAPPA2	SEN2	SPE2
41	3	0.4286	83.3	58.3	0.7059	100	66.7
42	3	0.5588	94.4	58.3	0.6269	100	58.3
43	3	0.1772	44.4	75	0.5714	88.9	66.7
44	3	0.2857	100	25	0.7059	100	66.7
45	3	0.3421	61.1	75	0.4776	94.4	50
46	3	0.3478	83.3	50	0.507	83.3	66.7
47	3	0.1096	61.1	50	0.5205	77.8	75
48	3	0.4928	88.9	58.3	0.5455	100	50
49	3	0.6377	94.4	66.7	0.6753	72.2	100
50	3	0.2857	100	25	0.6053	72.2	91.7
51	3	0.2254	72.2	50	0.7826	100	75
52	3	0.375	100	33.3	0.8571	100	83.3
53	3	0.6269	100	58.3	0.6575	83.3	83.3
54	3	0.3836	72.2	66.7	0.507	83.3	66.7
55	3	0.5714	88.9	66.7	0.6269	100	58.3
56	3	0.7059	100	66.7	0.8571	100	83.3
57	3	0.1935	100	16.7	0.7826	100	75
58	3	0.4595	72.2	75	0.4286	83.3	58.3
59	3	0.3284	88.9	41.7	0.7887	94.4	83.3
60	3	0.1463	33.3	83.3	0.3478	83.3	50

BIBLIOGRAPHY

[1] Angle EH. Classification of malocclusion. Dent Cosmos 1899; 41:248-64.

[2] Gravely JF, Johnson DB. Angle's Classification of Malocclusion: an assessment of reliability. Br J Orthod 1974; 1(3):79-86.

[3] Howat A. Orthodontics and health: have we widened our perspectives? Com Dent Health 1993; 10 Suppl 2:29-37.

[4] Katz RV. An epidemiological study of the relationship between various states of occlusion and the pathological conditions of dental caries and periodontal disease. J Dent Res 1978; 57:433-9.

[5] Shaw WC, Gabe MJ, Jones BM. The expectations of orthodontic patients in South Wales and St. Louis, MO. Br J Orthod 1980; 7:75-80.

[6] Richmond S, O'Brien KD, Roberts CT, Andrews. Dentists variation in the determination of orthodontic treatment need. Br J Orthod 1994; 21:65-68.

[7] Richmond S, O'Brien K, Buchanan I, Burden D. An introduction to occlusal indices. Ortho-care Pamphlet 1992.

[8] Brash JC, McKeag HT, Scott JH. The aetiology of irregularity and malocclusion of the teeth 2nd edition: the Dental Board of the United Kingdom, London 1956.

[9] Ast DB, Allaway N, Draker HL. The prevalence of malocclusion, related to dental caries and lost first permanent molars, in a fluoridated city and a fluoride-deficient city. Am J Orthod 1962; 48:106-113.

[10] Keeling SD, McGorray S, Wheeler TT, King GJ. Imprecision in orthodontic diagnosis: reliability of clinical measures of malocclusion. Angle Orthod 1996; 66(5):381-91.

[11] Turner SA. Occlusal indices revisited. Br J Orthod 1990; 17(3):197-203.

[12] Grainger RM. Orthodontic treatment priority index. Public Health Service Publication No. 1000, Series 2, No. 25. U. S. Department of Health, Education, and Welfare, Washington, D.C., 1967.

[13] Carlos JP. Evaluation of indices of malocclusion. Int Dent J 1970; 20:606-17.

[14] Lindauer SJ, Thresher AA, Baird BW, Sheats RD, Rebellato J. Orthodontic treatment priority: a comparison of two indices. J Clin Ped Dent 1998; 22(2):125-31.

[15] Salzmann JA. Handicapping malocclusion assessment to establish treatment priority. Am J Orthod 1968; 54:749-65.

[16] AAO Proceedings of the orthodontic indices consensus conference 1993. St. Louis: American Association of Orthodontists.

[17] Draker HL. Handicapping labio-lingual deviations: a proposed index for public health purposes. Am J Orthod 1960; 46:295-305.

[18] Younis JW, Vig KW, Rinchuse DJ, Weyant RJ. A validation study of three indexes of orthodontic treatment need in the United States. Com Dent Oral Epi 1997; 25(5):358-62.

[19] Richmond S, Shaw WC, O'Brien KD, Buchanan IB, Jones R, Stephens CD, Roberts CT, Andrews M. The development of the PAR Index (Peer Assessment Rating) : reliability and validity. Eur J Orthod 1992; 14(2):125-39.

[20] So LL, Tang EL. A comparative study using the Occlusal Index and the Index of Orthodontic Treatment Need. Angle Orthod 1993; 63(1):57-64.

[21] Summers CJ. The occlusal index: a system for identifying and scoring occlusal disorders. Am J Orthod 1971; 59:552-67.

[22] Beglin FM. Validation of three indices of orthodontic treatment need. MS Thesis 1997. Columbus, OH: The Ohio State University.

[23] Cons NC, Jenny J, Kohout FJ. DAI: The dental aesthetic index. Iowa City: College of Dentistry, University of Iowa 1986.

[24] Brook PH, Shaw WC. The development of an index of orthodontic treatment priority. Eur J Orthod 1989; 11:309-20.

[25] Linder-Aronson S. Orthodontics in the Swedish Public Dental Health System. Transactions of the European Orthodontic Society 1974; 233-240.

[26] Evans R, Shaw W. Preliminary evaluation of a illustrated scale for rating dental attractiveness. Eur J Orthod 1987; 9:314-318.

[27] Shaw WC, Richmond S, O'Brien KD, Brook P, Stephens CD. Quality control in orthodontics: indices of treatment need and treatment standards. British Dental Journal 1991; 170(3):107-12.

[28] Jones CM, Woods K, O'Brien K, Winard C, Taylor GO. Index of Orthodontic Treatment Need, its use in a dental epidemiology survey calibration exercise. Community Dental Health 1996; 13(4):208-10.

[29] Holmes A, Willmot DR. The Consultant Orthodontist Group 1994 survey of the use of the Index of Orthodontic Treatment Need (IOTN). Br J Orthod 1996; 23(1):57-9.

[30] Richmond S, Buchanan IB, Burden DJ, O'Brien KD, Andrews M, Roberts CT, Turbill EA. Calibration of dentists in the use of occlusal indices. Community Dentistry & Oral Epidemiology 1995; 23(3):173-6.

[31] Lunn H, Richmond S, Mitropoulos C. The use of the index of orthodontic treatment need (IOTN) as a public health tool: a pilot study. Com Dent Health 1993; 10(2):111-21.

[32] Burden DJ, Garvin W, Patterson CC. A field trial of an orthodontic treatment need learning package for general dental practitioners. British Dental Journal 1997, 183 (4):123-9.

[33] Shaw WC, Richmond S, O'Brien KD. The use of occlusal indices: a European perspective. American Journal of Orthodontics & Dentofacial Orthopedics 1995; 107(1):1-10.

[34] Brightman BB, Hans MG, Wolf GR, Bernard H. Recognition of malocclusion: An education outcomes assessment. Am J Orthod Dentofac Orthop 1999; 116(4):444-51.

[35] Roethlisberger FT, Dickson WJ. Management and the worker. Harvard University Press; 1939.

[36] Buchanan IB, Downing A, Stirrups DR. A comparison of the Index of Orthodontic Treatment Need applied clinically and to diagnostic records. Br J Orthod 1994; 21(2):185-8.

[37] DeGuzman L, Bahiraei D, Vig KW, Vig PS, Weyant MS, O'Brien K. The validation of the Peer Assessment Rating Index for malocclusion severity and treatment difficulty. Am J Orthod 1995; 107:172-176.

[38] Popovich F, Thompson GW. A longitudinal comparison of the orthodontic treatment priority index and the subjective appraisal of the orthodontist. J Pub Health Dent 1971; 31:2-8.

[39] Grummons DC, Kappeyne van de Coppello MA. A frontal asymmetry analysis. J Clin Orthod 1987; 21: 448-65.

[40] Cohen, AJ. A coefficient of agreement for nominal scales. Educational and Psychological Measurements 1960; 20:37-46.

[41] Bartko JJ. On various intraclass correlation reliability coefficients. Psychol Bull 1976; 83:762-65.

[42] Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics 1977; 33: 159-74.

[43] Severiens SE, Ten Dam GTM. Gender differences in learning styles: a narrative review and quantitative meta-analysis. Higher Ed 1994; 27:487-501.

[44] Linn MC, Petersen AC. Emergence and characterization of sex differences in spatial ability: A meta-analysis. Child Dev 1985; 56:1479-98.

[45] Kail R, Carter P, Pellegrino J. The locus of sex differences in spatial ability. Perception and Psychophysics 1979; 26: 182-186.